THE EFFECTIVENESS OF CONGESTION COUNTERMEASURES BY USING LED IMFORMATION BOARDS AT CHUO EXPRESSWAY IN JAPAN

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ABSTRACT

This paper describes the effectiveness of countermeasures by using Light Emitting Diode (LED) information boards, which is one of the countermeasures recently attempted to reduce congestion on Chuo Expressway, Japan. The LED information boards, installed near the bottlenecks at sag and merging sections, provide drivers with information that is enable to urge the drivers to accelerate or to adjust the balance of traffic lane utilization. In order to evaluate the performance with LED information boards, an experiment was executed in a study section where congestion often occurs and a comparison analysis of flow rate, speed and lane utilization rate between with and without LED information boards was undertaken. The results showed that the present LED information boards have some effects on improving flow rate, speed and lane utilization rate at bottlenecks. We concluded that the countermeasures using LED information boards would be one of the effective countermeasures in reducing congestion at low cost without changing road structure.

1. INTRODUCTION

Traffic Congestion seriously affects our economy, quality of life and environment not only in Japan but also in any countries all over the world. Therefore, mitigating congestion is a high priority for us. Chuo Expressway, from Tokyo to Nagoya, is one of the most important components of the transportation network in Japan. On the Expressway in large cities and vicinities, congestion is often caused by weekend recreational traffic or workday. Much of the congestion is due to geometric bottlenecks such as sag sections, merging areas and tunnels. In order to alleviate congestion, it is clear that adding more lanes to existing expressways is very effective. In some metropolitan area, however, it is difficult to undertake major road expansions mainly because of construction costs and right-of-way constraints. Since road building alone will not solve the problem, a variety of countermeasures have been carried out to make best use of existing expressways, such as implementing traffic demand management for weekend recreational traffic, providing real-time information on present traffic conditions and traveler information of congestion forecast especially for holiday season when traffic demand increases.
As well as the above mentioned countermeasures to make best use of existing expressways, the countermeasures using LED information boards is used on Japan's Expressways. The present

countermeasures have already been implemented in several sections on Japan's Expressways. To examine the case of countermeasures using LED information boards, latest information was collected from some literatures (from [1]-[4]), internet website (from [5], [6]) and some transportation practitioners. The collected information is described in the following chapter.

2. EALIER EXAMPLES

The countermeasures using LED Information Board have already been executed in several sections on Japan's Expressways. From ealier examples we collected, it is found that the intended use of LED information boards is made to classify two types depending on causes of congestion. One is a type to provide speed recovery information to drivers near the bottleneck in sag sections. Sag sections are known as bottlenecks as well as some obvious bottlenecks such as merging or diverging sections and weaving sections on Japanese Expressways. From many earlier empirical studies, its cause showed that drivers frequently slow down unconsciously in sag sections because they are not aware of grade change. Traffic also concentrates in inner lanes where congestion begins with available traffic capacity not fully utilized. The other is a type to be installed in the vicinity of merging area, and to provide information that improve lane utilization rate. It is fact that traffic congestion frequently occurs at merging area, especially during heavy traffic demand, because entering and exiting traffic causes disturbances to traffic on multilane facilities.

2.1 An Example Of Measures At Sag Section

Figure 1 shows a case where measures are executed in the consecutive sag sections on Tomei Expressway. The present LED information boards provide drivers with information that is enable to urge the drivers not to fall speed down in the vicinity of each bottleneck before congestion occurs in order to delay occurrence of congestion. Once congestion occurs, the displayed message of the boards changes the speed recovery information. Messages displayed on the boards change automatically in response to traffic conditions with the aim of improving traffic flows. According to asking to the on-site transportation practitioners, it appears that the execution of measures is effective in alleviating congestion, compared without measures.

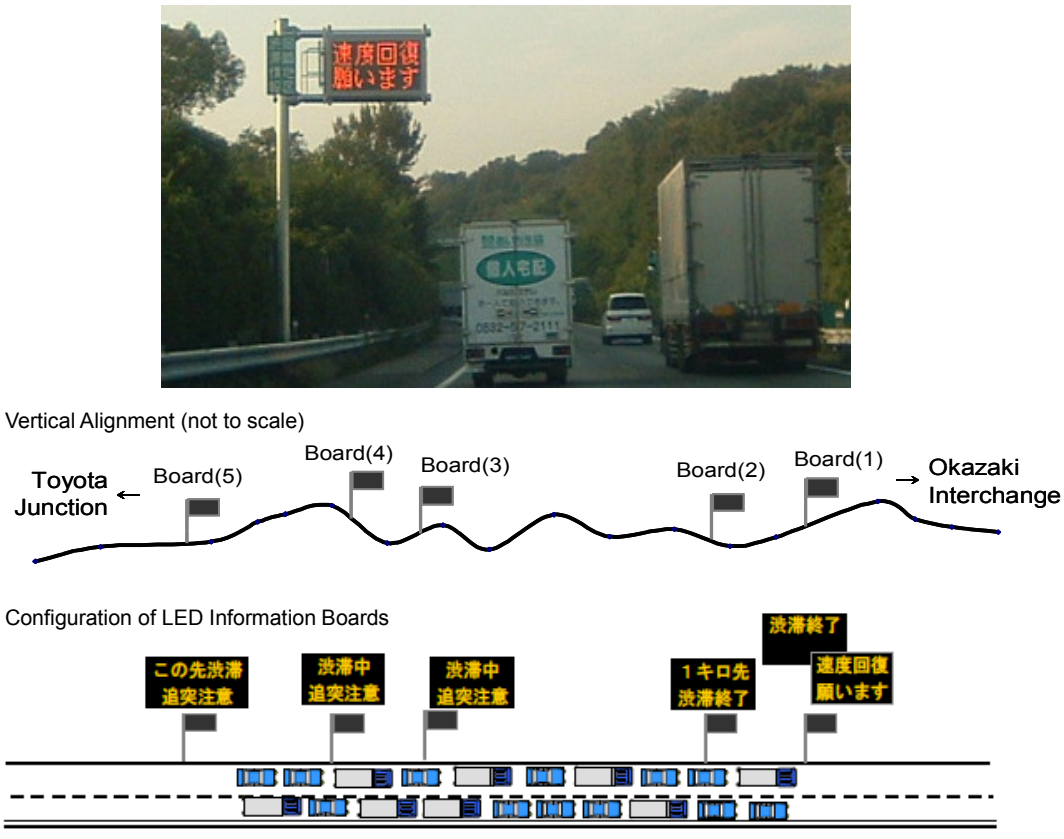


Figure 1: LED Information boards at sag section
(Okazaki Area on Tomei Expressway)

2.2 An Example Of Measures At Merging Area

The following case is the second type of measures using LED information boards as shown in Figure 2. In order to prevent congestion from occurring during high traffic volumes caused by inequal lane utilization of two lanes at merging area, LED sign cars is installed at the downstream of merging area. Entering drivers from on-ramp are provided with “Keep Left” message immediately after merging and can choke off transferring from outer lane to inner lane. The present measure reports positive results that LED sign cars improve traffic conditions on speed-flow relationship and lane utilization rate (from [2]).

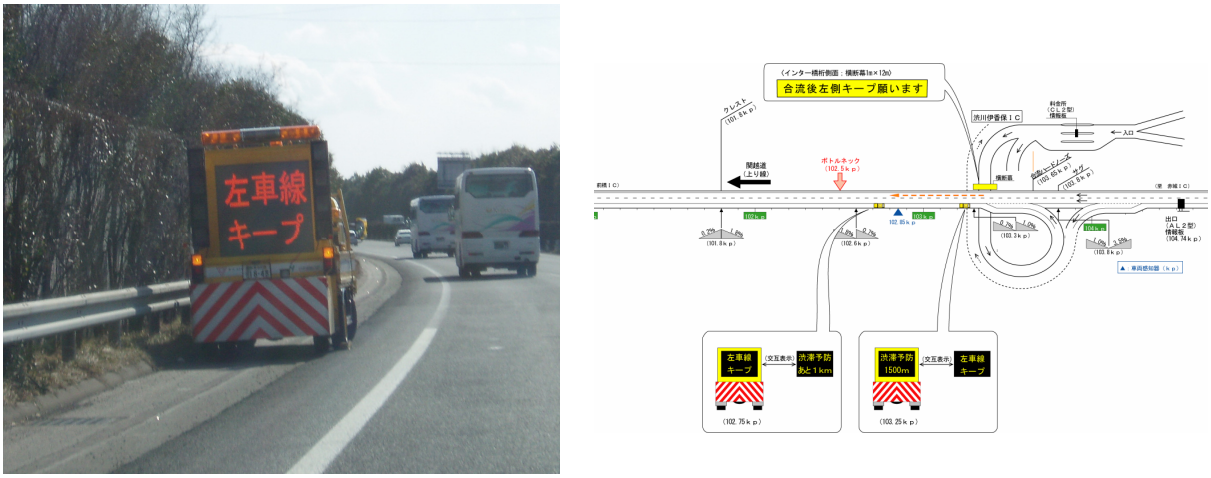


Figure 2: LED sign cars installed on the hard shoulder
(Shibukawa-Ikaho Interchange on Kanetsu Expressway)

3. STUDY OBJECTIVES

Besides the above-mentioned, the countermeasures using LED information boards or LED sign cars have been implemented at many sites on Japan’s Expressways and showed good results in reducing congestion. However until now, there is no case of having carried out simultaneously the present two types of measures in the consecutive section including two bottlenecks where merging and sag sections are adjacent. We selected as study section such a consecutive section including two bottlenecks on Chuo Expressway. The objective of the empirical study is to perform the experimental measures with LED information boards, and to evaluate the performance on traffic conditions, that is, flow rate, speed and lane utilization rate.

4. STUDY AREA AND METHOD OF EXPERIMENTAL COUNTERMEASURE

The study area is an inbound two-lane section of Chuo Expressway. This section is located about 20 km west from the center of Tokyo, where the congestion occurs over 150 times a year because of carrying traffic to the central business district of Tokyo during the morning peak period. Some earlier researches report that this section has two bottlenecks. One is merging section located around 6.8 kilometer-post(kp), which is called “Chofu Interchange Merging Area”, and the other is sag section located around 5.0 kp, which is called “Jindaiji Bus Stop Sag”. Figure 3 shows vertical alignment, plan view, location of the above two bottlenecks, and configuration of LED information boards in the study area.

4.1 Installation of the LED Information Board

As shown in Figure 4, the LED information boards were installed temporarily on the hard shoulder in the study area, which is equal to the type of LED information boards often used on worksite. In general, LED sign cars is used when experimented on other Japan’s Expressways, but the LED sign cars cannot be put in the study section because the one is bridge sections with narrow hard shoulder. Therefore, we selected the temporary LED information boards in this study section, and also the experimental period was limited at the peak time in the morning when congestion often occurs.

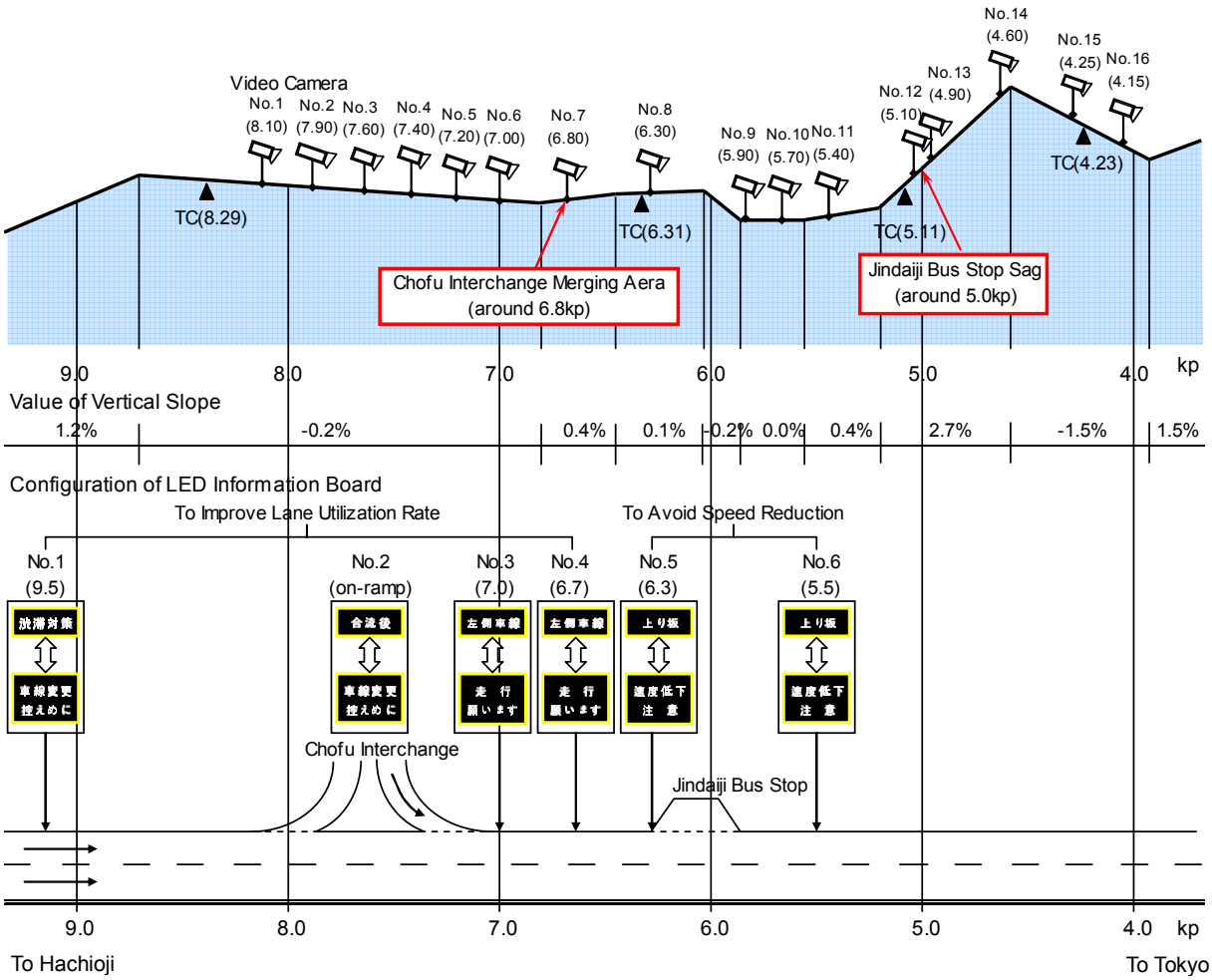


Figure 3: Vertical alignment, plan view, configuration of LED information boards

Figure 4: LED information board set up temporarily on the hard shoulder
(In the vicinity of Chofu Interchange on Chuo Expressway)

4.2 Display of the LED Information Board

Messages displayed on the LED information boards are shown in Table 1. As for the LED information boards from No.1 to No.4 installed in merging area, the messages on the boards to improve the lane utilization rate is offered to drivers. At the same time, the messages from No.5 to No.6 installed in sag sections provide drivers with information in order to make them recognize that there is an upgrade section ahead reducing speed easily.

Table 1: Display of the LED information board

LED Information Board No.	Display Message	Installation Position	Main Purpose of Measures
No.1	Congestion Measures <-----> Hold back Lane Change	9.5kp	To improve lane utilization rate
No.2	After Merging <-----> Hold back Lane Change	Chofu Interchange on-ramp	
No.3	Left Lane <-----> Go Ahead	7.0kp	
No.4	Left Lane <-----> Go Ahead	6.7kp	
No.5	Upgrade Ahead <-----> Caution! Speed Down	6.3kp	To avoid speed reduction
No.6	Upgrade Ahead <-----> Caution! Speed Down	5.5kp	

<----->: Alternate message

5. PERFORMANCE MEASURE EVALUATION

5.1 Data Collection

In the study section, congestion often occurs in the morning on weekdays. Therefore, the experiment was performed for 8 weekdays in December of 2008 as shown in Table 2. The experimental period was from 6:00 a.m. to the end of congestion each day. The data used for the comparison analysis with and without LED information boards was obtained from detectors which include volume, average spot speed, heavy vehicle composition and occupancy. In order to get data about traffic volume, speed, and lane changing maneuvers especially at merging sections, video cameras were also used at all sixteen locations. The cameras faced in the same direction as traffic. The camera data were collected from December 15 to December 19. The location of detectors and video cameras is shown in Figure 3.

5.2 Method of Analysis

In the study, two types of experimental measures using LED information boards were carried out. One is the measures against “Chofu Interchange Merging Area” where LED information boards provide drivers with information to improve the lane utilization rates of both lanes from the upstream and the downstream in merging sections around Chofu Interchange. The other is the measures against “Jindaiji Bus Stop Sag” where providing drivers with information to urge the drivers to avoid speed reduction or to accelerate.

In the analysis, the above two types of measures were evaluated respectively because the station where the data used for analysis was obtained from the detectors and the video cameras was different.

When evaluating the performance with LED information boards, indicators to be addressed by the evaluation are three kinds of data, that is, flow rate, speed and lane utilization rate between with and without LED information boards.

Figure 6 shows speed contour maps during the experiment period where data is obtained by detectors installed along expressway with 5-minute mean speed. As can been seen in Figure 6, congestions occurring in the downstream reached the experiment section depending on the traffic conditions each day. Such data were excluded in the comparison analysis.

Table 2: Date of the experiment with or without LED information board

Date	With or Without LED Information Board	Bottlenecks	Period of Analysis	Time number of Analysis
Dec. 15 Mon	Without	Chofu Interchange Merging Area	6:00-8:45	2:45
Dec. 16 Tue	With	Chofu Interchange Merging Area	6:00-7:40	1:40
Dec. 17 Wed	Without	Jindaiji Bus Stop Sag	6:00-10:15	4:15
Dec. 18 Thu	With	Chofu Interchange Merging Area	6:00-8:20	2:20
Dec. 19 Fri	Without	Jindaiji Bus Stop Sag	6:00-9:35	3:35
Dec. 22 Mon	With	Jindaiji Bus Stop Sag	6:00-9:35	3:35
Dec. 25 Thu	With	Jindaiji Bus Stop Sag	6:00-9:40	3:40
Dec. 26 Fri	With	Jindaiji Bus Stop Sag	6:00-9:10	3:10

5.3 Flow Rate Before and After Congestion With / Without LED Information Board

In the analysis, two types of flow rate are compared with and without LED information boards. One is breakdown flow rate (or capacity just before congestion) and the other is queue discharge flow rate (or capacity during congestion). Occurrence of congestion or breakdown is assumed for a traffic condition when 5-min space mean speed drops below 40km/hr and it continues for over 15 minutes. Breakdown flow rate is defined as an averaged value in 5-minite of vehicles observed in a 15-minute just before congestion, while queue discharge flow rate is defined as an average flow rate during congestion. An example of two types of flow rate are shown in Figure 5.

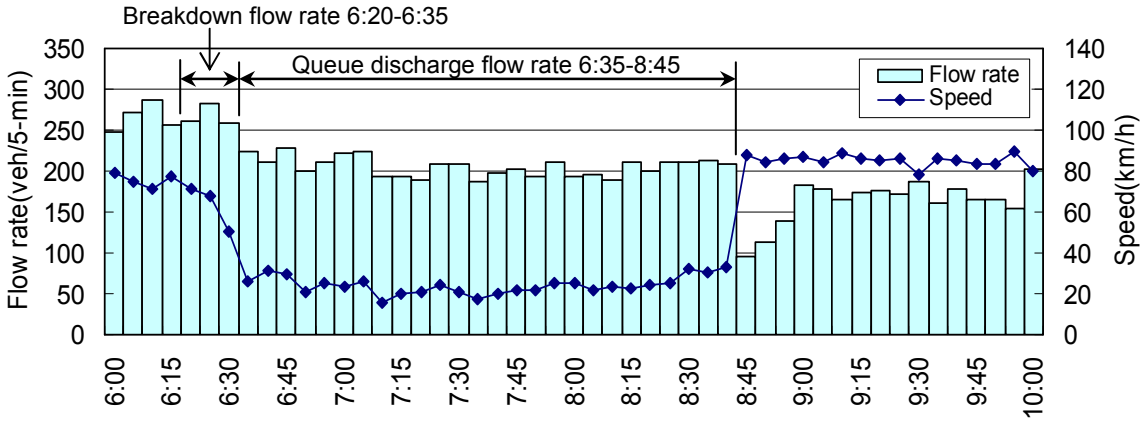
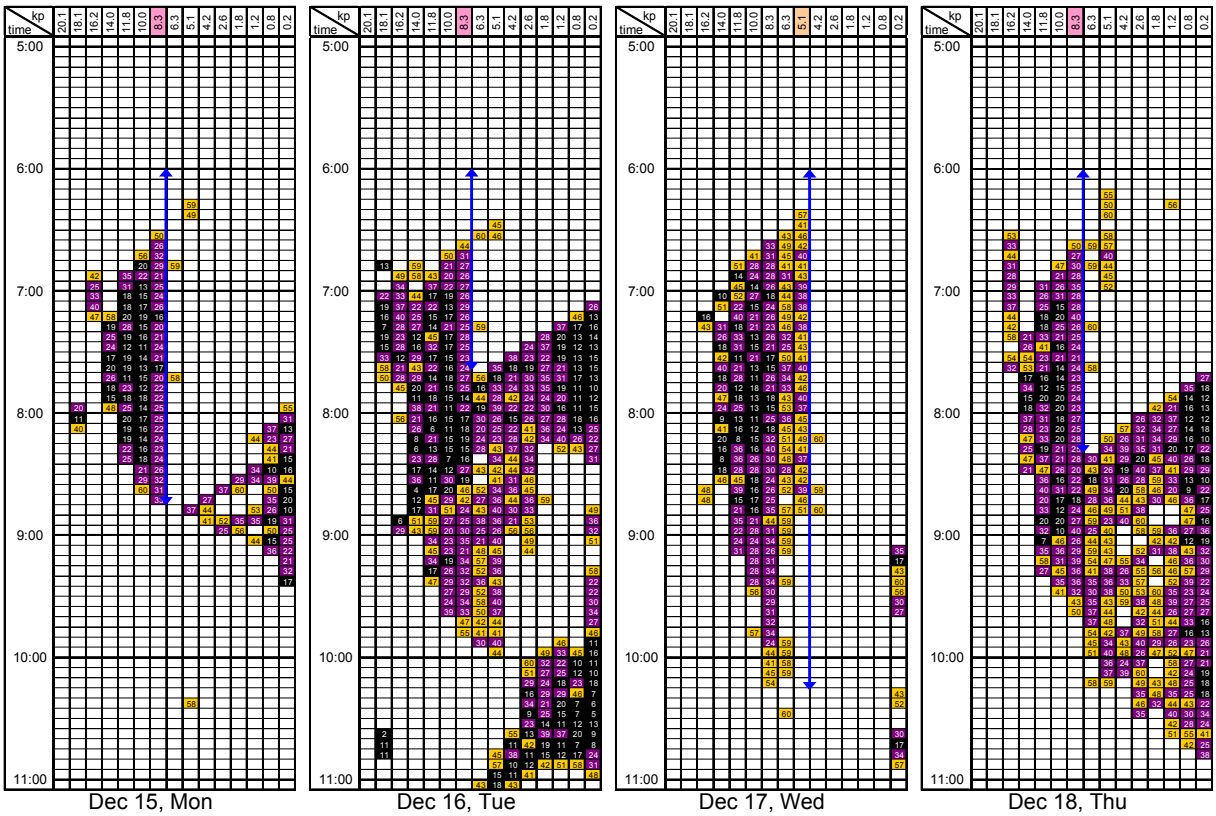


Figure 5: Definition of breakdown flow rate and queue discharge flow rate
(8.1kp Inbound of Chou Expressway, Dec. 15, 2008)

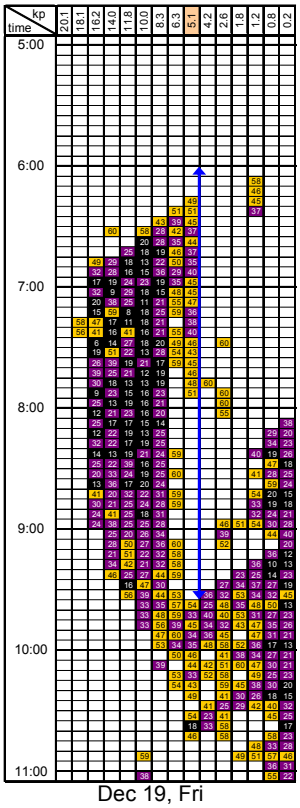


Dec 15, Mon
Measure: Without
Bottleneck: Chofu Merging

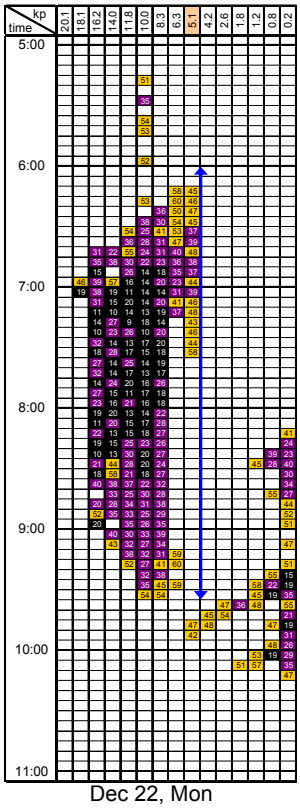
Dec 16, Tue
Measure: With
Bottleneck: Chofu Merging

Dec 17, Wed
Measure: Without
Bottleneck: Jindaiji Sag

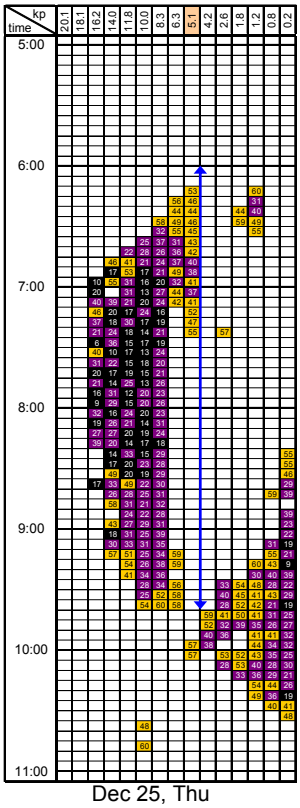
Dec 18, Thu
Measure: With
Bottleneck: Chofu Merging



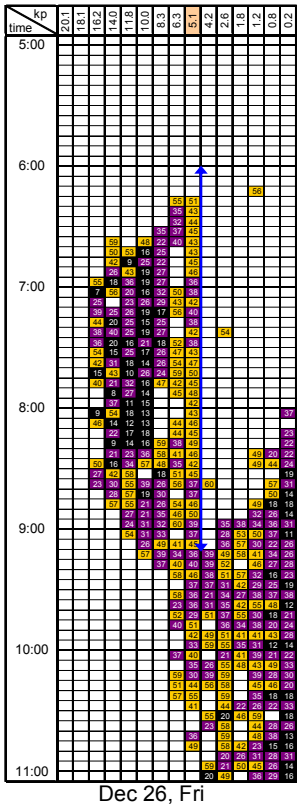
Dec 19, Fri
Measure: Without
Bottleneck: Jindaiji Sag



Dec 22, Mon
Measure: With
Bottleneck: Jindaiji Sag



Dec 25, Thu
Measure: With
Bottleneck: Jindaiji Sag



Dec 26, Fri
Measure: With
Bottleneck: Jindaiji Sag

Figure 6: Speed contour map for the experiment period

(LEGEND) 5-min space mean speed in all lanes:

15 ≦ 20 km/h 20 km/h < 25 ≦ 40 km/h 40 km/h < 50 ≦ 60 km/h 60 km/h <

Period of analysis: ←→

Based on the above, the results on two types of flow rates are presented as shown in Figure 7 and 8. Compared with the case without LED information boards at “Chofu Interchange Merging Area” by the day (Figure 7), the above both flow rates with LED information boards increases. Likewise compared, at “Jindaiji Bus Stop Sag” (Figure 8), it was only a day (Dec 22) that some increase of breakdown flow rates with LED information boards was observed. Queue discharge flow rates with LED information boards are also stayed in a slight increase. In this, it seems that it is not property evaluated due to the lack of the number of sample data defined above (refer to Figure 6).

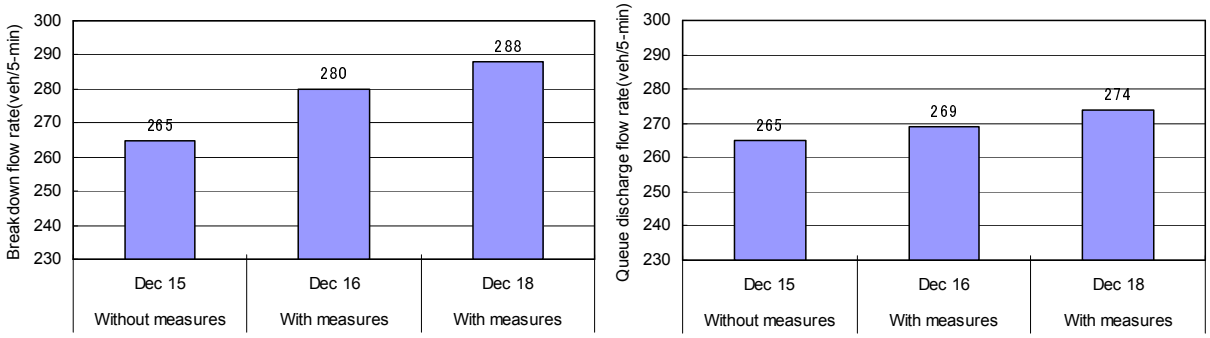


Figure 7: Changes in flow rate with and without LED information boards
Bottleneck at “Chofu Interchange Merging Area” (Data source: the station at 8.1kp detector)

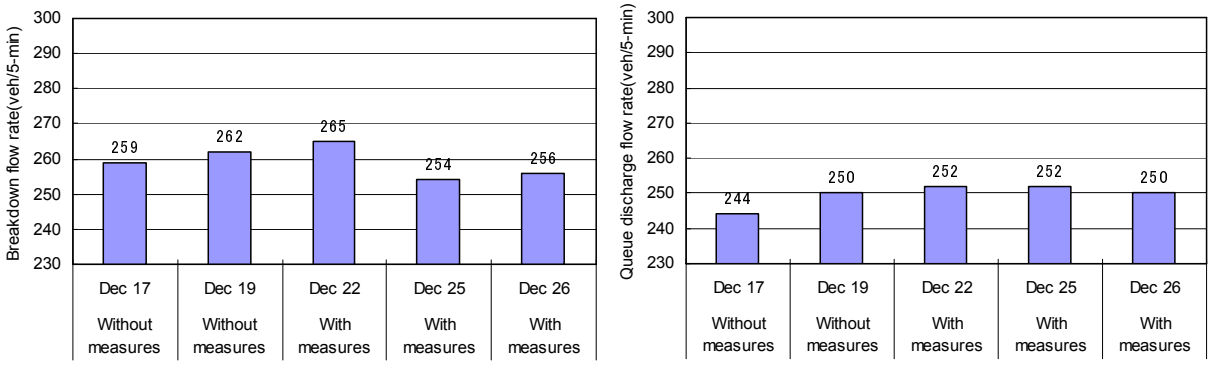


Figure 8: Changes in flow rate with and without LED information boards
Bottleneck at “JIndaiji Bus Stop Sag” (Data source: the station at 5.1kp detector)

5.4 Lane Utilization Rate Before Congestion With / Without LED Information Board

Lane utilization rate comparison was analyzed to understand how LED information boards is affected the distribution of traffic between lanes, compared to the case without LED information boards. The comparison of lane utilization rate between with and without LED information boards was undertaken along the study section. The data used for the analysis focuses on the maximum value of 5-min mean flow rates just before congestion obtained from detectors and video cameras.

Figure 9-11 presents an example of results when congestion occurs at “Chofu Interchange Merging Area”. As shown in the Figures, visible changes in the utilization rate between the station from 7.6kp to 6.8kp are due to the existence of the on- and off-ramp at Chofu Interchange. When the case without LED information boards (Figure 9) and with LED information boards (Figure 10, 11) were compared, the results show that the lane utilization rate with LED information boards drops in inner lane of the station at 6.8kp although the lane utilization rates in inner lane on the upstream shows high values as shown in Figure 10, compared to the ones shown in Figure 9. Moreover, the results also show that the decreasing tendency of the lane utilization rates in inner lane extends to the downstream.

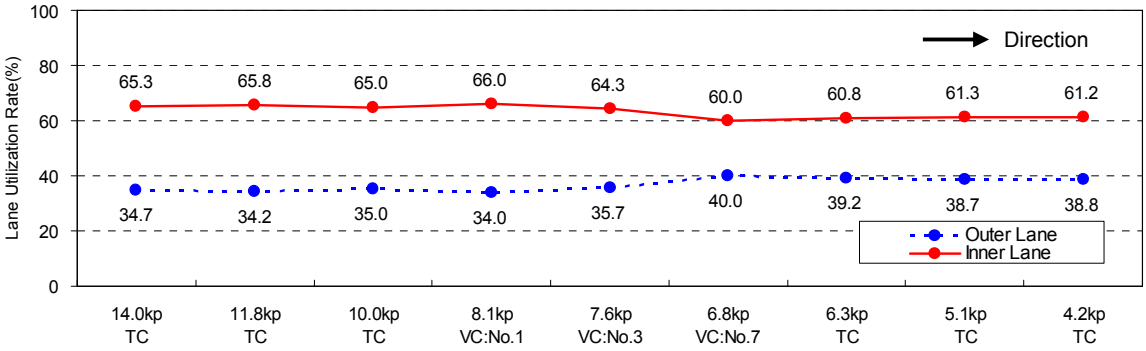


Figure 9: Spatial variance of lane utilization rate along the study section
(Data of 6:25 on Dec 15 without LED information boards)

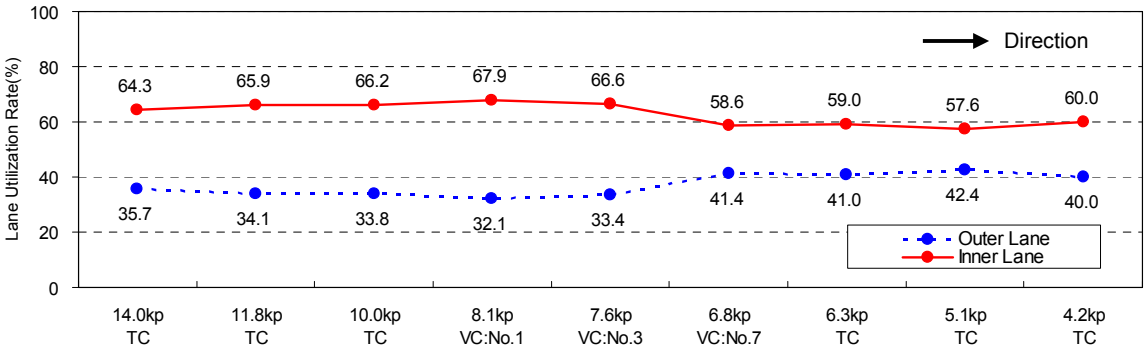


Figure 10: Spatial variance of lane utilization rate along the study section
(Data of 6:30 on Dec 16 with LED information boards)

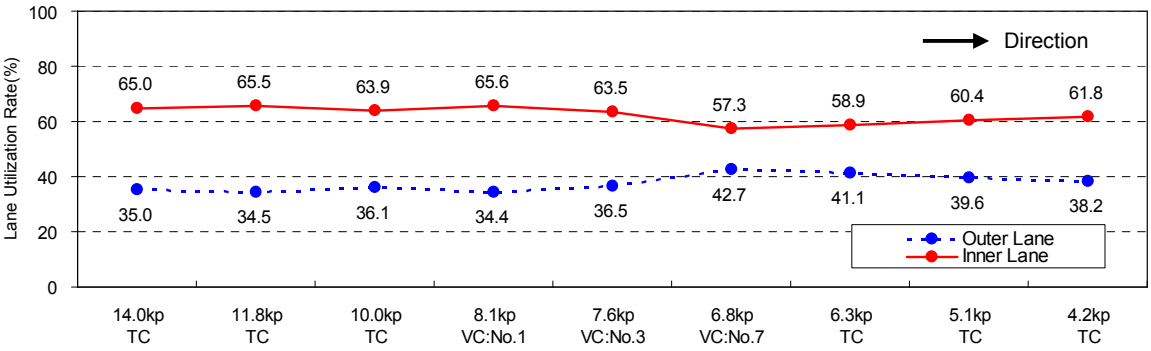


Figure 11: Spatial variance of lane utilization rate along the study section
(Data of 6:30 on Dec 18 with LED information boards)

Note: The station at 8.1kp is just a short distance downstream of the off-ramp at Chofu Interchange.
The station at 7.6kp is just a short distance upstream of the on-ramp at Chofu Interchange

5.5 Speed- Flow Relationship With / Without LED Information Board

The speed flow relationship with and without LED information board at a location just downstream of the section installed LED information boards, are shown in Figure 12. Data from the above period of analysis at location 5.1kp was used to represent the performance evaluation of LED information board. When comparing the flow/speed plots with and without LED information board, the following observations can be made:

- LED information board has slightly increased the breakdown flow rate in inner lane.
- LED information board also has slightly increased the queue discharge flow rate in both lanes.
- LED information board has resulted in a larger cluster of data points around 60km/hr speed level.
- LED information board also has slightly increased breakdown and queue discharge flow rate in outer lane.

The above observations have shown supporting evidence that LED information board increases flow rate of bottlenecks as shown in Figure 7-8 and improves the inequality of lane utilization as shown in Figure 9-11.

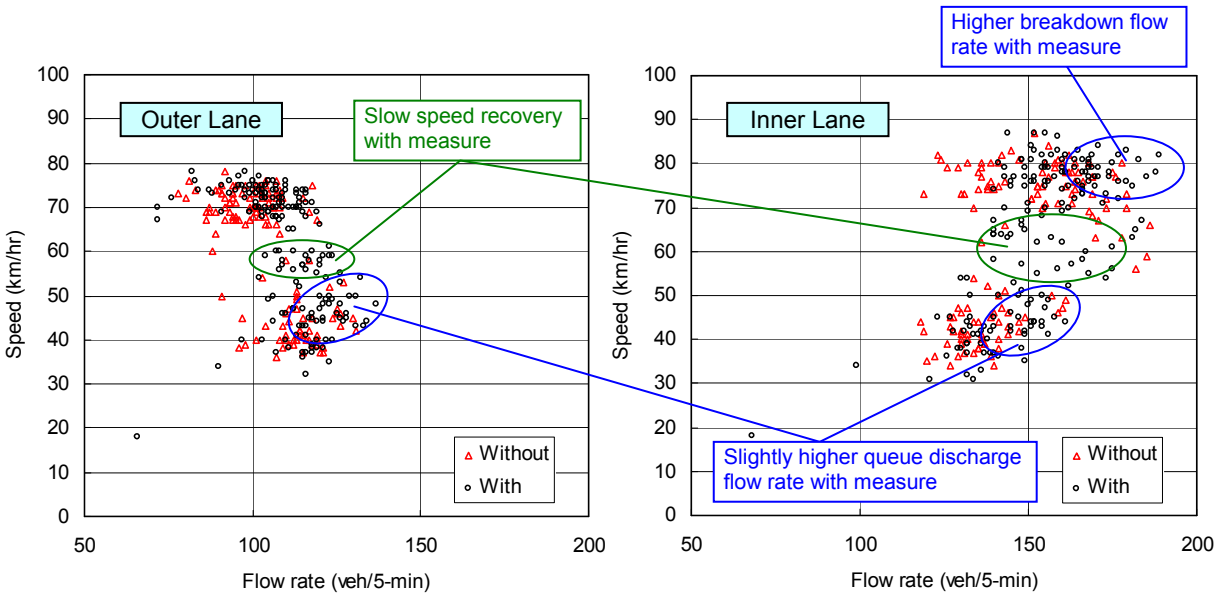


Figure12: Flow-speed relationship (Data source: the station at 5.1kp detector)

6. SUMMARY AND CONCLUSIONS

In the study, two types of experimental measures using LED information boards were carried out. One is the measure against “Chofu Interchange Merging Area” where LED information boards provide drivers with information to improve the lane utilization rates of both lanes from the upstream and the downstream in merging sections around Chofu Interchange. The other is the measure against “Jindaiji Bus Stop Sag” where drivers were provided with the information to urge them to avoid speed reduction or to accelerate.

The objective of the study was to evaluate the performance of the LED information board on traffic conditions, that is, flow rate, speed and lane utilization rate focusing on just before or after congestion. The main findings of the study can be summarized as follows:

- LED information boards have increased the breakdown and queue discharge flow rate at “Chofu Interchange Merging Area”. However, it was not clearly confirmed that the above two flow rates increased at “jindaiji Bus Stop Sag”.
- LED information boards have an effect on improving lane utilization rates. Moreover it was found that the improved lane utilization rate continues to the downstream of bottlenecks.
- LED information boards have recovered slow speed level in saturated traffic condition.

From the above-mentioned results, it was found that the measures using LED information boards had some effects on reducing congestion. However, it is conceivable that continuous investigations are necessary in the future because the data addressed in the study was limited.

REFERENCES

[1] SAITO Y., XING J., NONAKA Y., ISHIDA T., UCHIYAMA H.(2005): An Experimental Study on Mitigating of Expressway Traffic Congestion with LED information Board, Proceedings of Eastern Asia Society for Transportation Studies, Vol.5, pp.919-928

[2] HARADA S., FUKASE M., MAEJIMA K., SATO H., SEKO K.(2007): Congestion Measures Effect of Expressway by Lane Availability Leveling, Journal of JSCE, Vol.42, No.5 (in Japanese)

[3] Nakatani R., Minagata T., Sato H., Ichikawa M.(2005): Evaluation on effect of provision of speed increase advice message by LED sign in consideration of time spent in queue, Proc. of the 25th JSTE Annual Conference (in Japanese)

[4] Xing J., Takahashi H., and Takeuchi T.,(2007): Mitigation of expressway traffic congestion with simple variable message sign, the 14th World Congress on ITS Beijing

[5] Central Nippon Expressway Co., Ltd., Homepage:
http://www.c-nexco.co.jp/info/others/pdf/20090423/20090423_01.pdf (in Japanese)

[6] East Nippon Expressway Co., Ltd., Homepage:
http://www.e-nexco.co.jp/pressroom/press_release/head_office/h18/0908/ (in Japanese)